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Consolidate or Improve? The Small Data Center Question

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Pacific Northwest National Laboratory

Ralph Wescott
Data Center Manager



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There is much you could do at sea with common sense..
and very little you could do without it..”

Capt G E Ericson from “the Cruel Sea” by Nicholas Monsarrat

PNNL

- A multi-program research laboratory
- FY 2017 business volume \$987M
- 4,500 staff
- 10,000+ networked devices
- Unique laboratory equipment
- Scientific supercomputing



PNNL Data Center Efficiency

- Rebuild Main Data Center
 - Power
 - Space
 - Cooling
 - 2005-2010
- Consolidate Multiple Data Centers
 - Reduce from 26 down to 3
 - 2011-2013
- Ongoing Efficiency Improvement
 - 2014-present

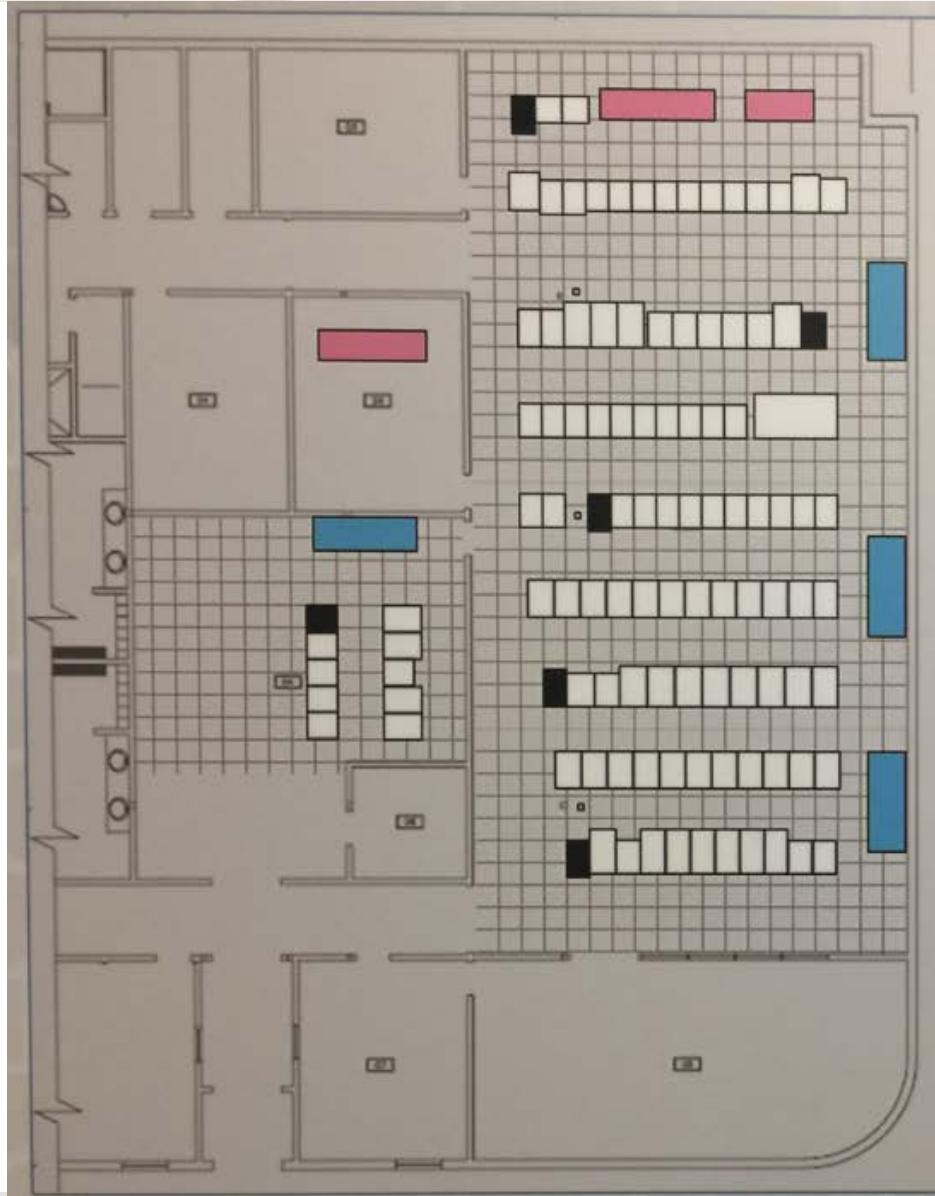
Starting/Breaking Point

- 3,000 sq. ft. Data Center, Campus Network and Business Systems focal point
- 60 tons AC with 3 HVAC's, no backup
- 195KVA power consumption
- All rows face same direction
- Zero free space on floor or in racks
- 130KVA UPS, remainder City Power
- Straddled Power (split City and UPS)
- Datacenter temperature = ~87°F (warmest location)
- Server installations “at will”
- Power “blips” caused outages
- July 2005 overloaded circuit breaker (and the healing began)

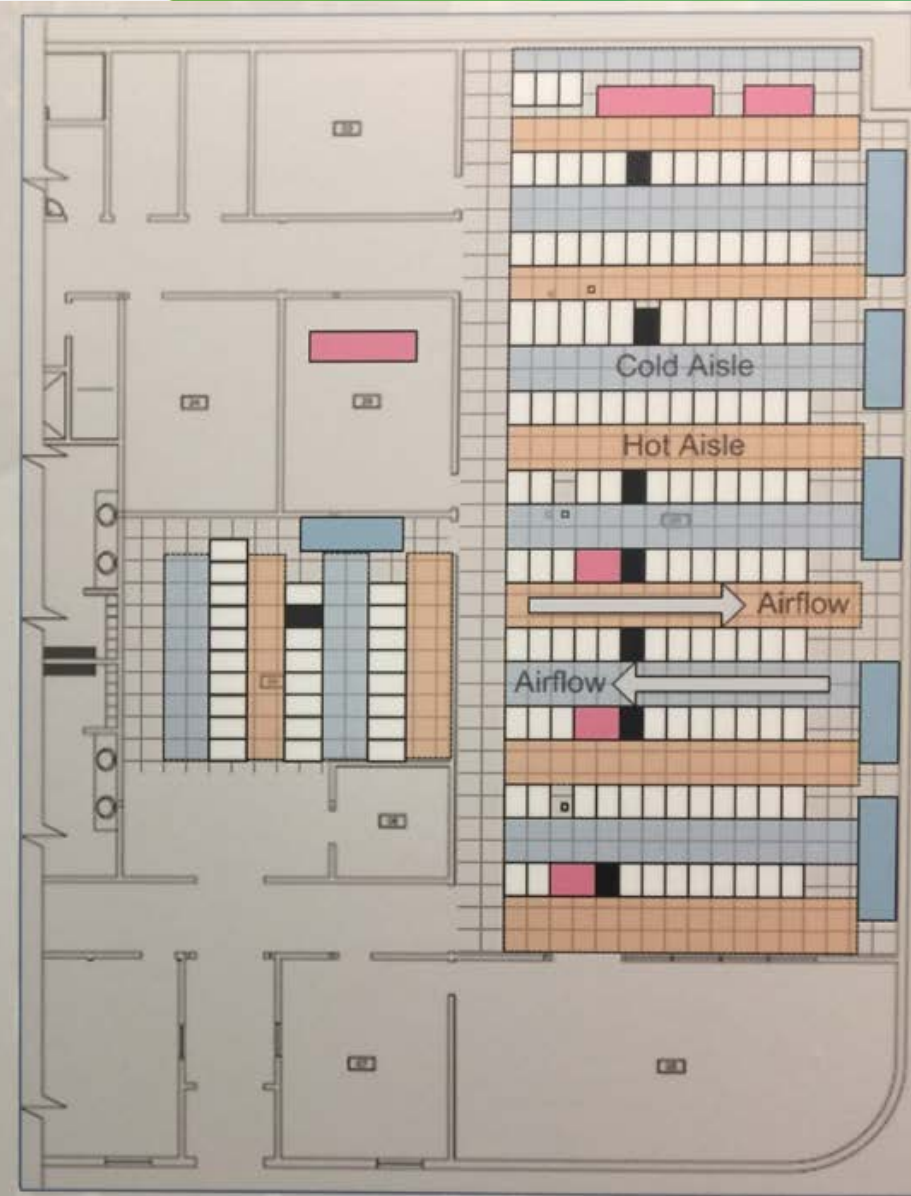
Setting the Goals

- Increase Cooling and Air Distribution
- Increase City Power (building only 500kVA capable)
- Increase UPS Power
- Increase Free Space
- Implement Best Practices and Standards from:
 - ASHRAE
 - APC White Papers
 - Uptime Institute
 - 7x24 Exchange
- Minimize Downtime During Transition
- Budget (many iterations)
- 100% Power Monitoring
- Satisfy Growth For Next 5 Years

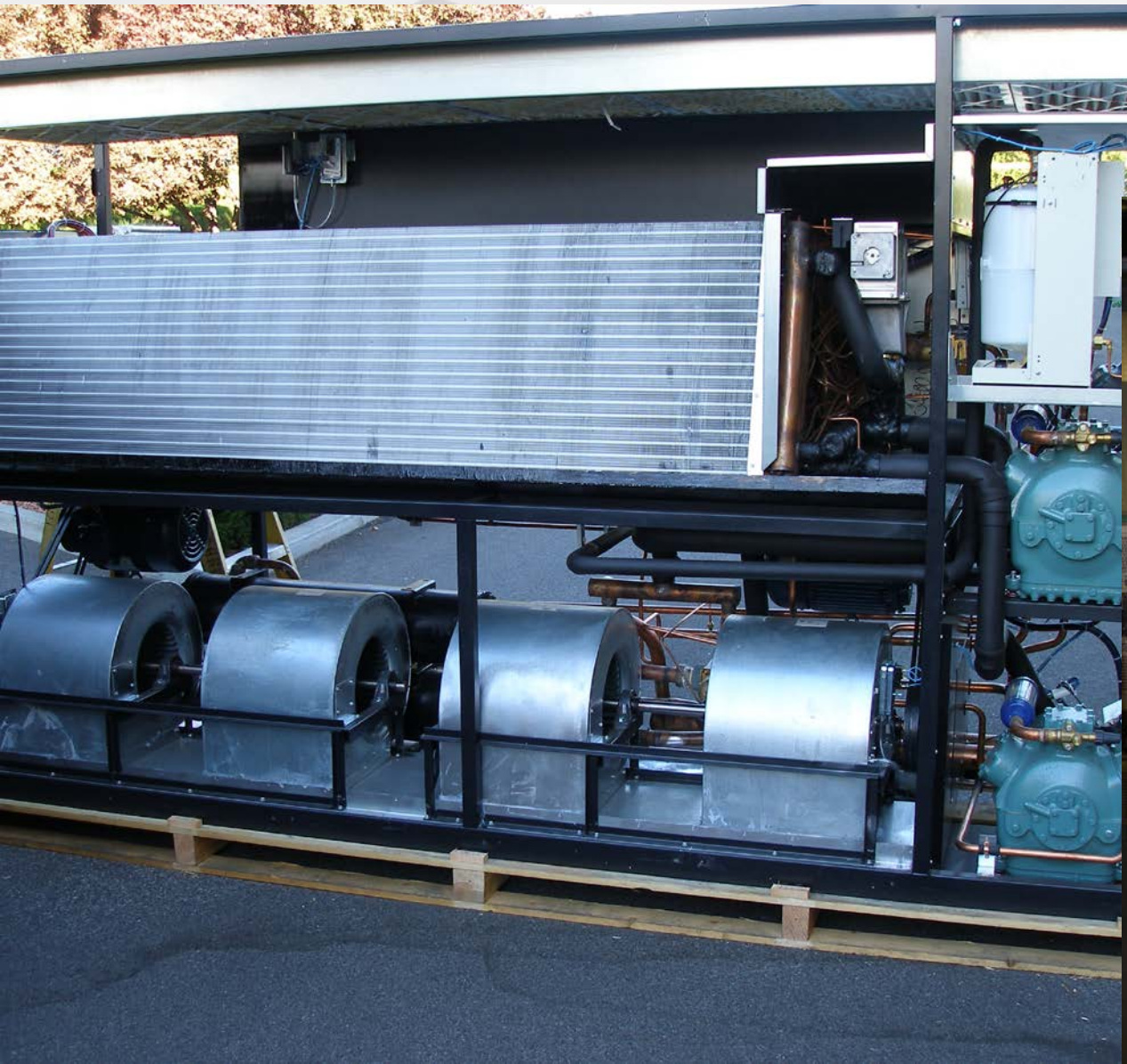
Before



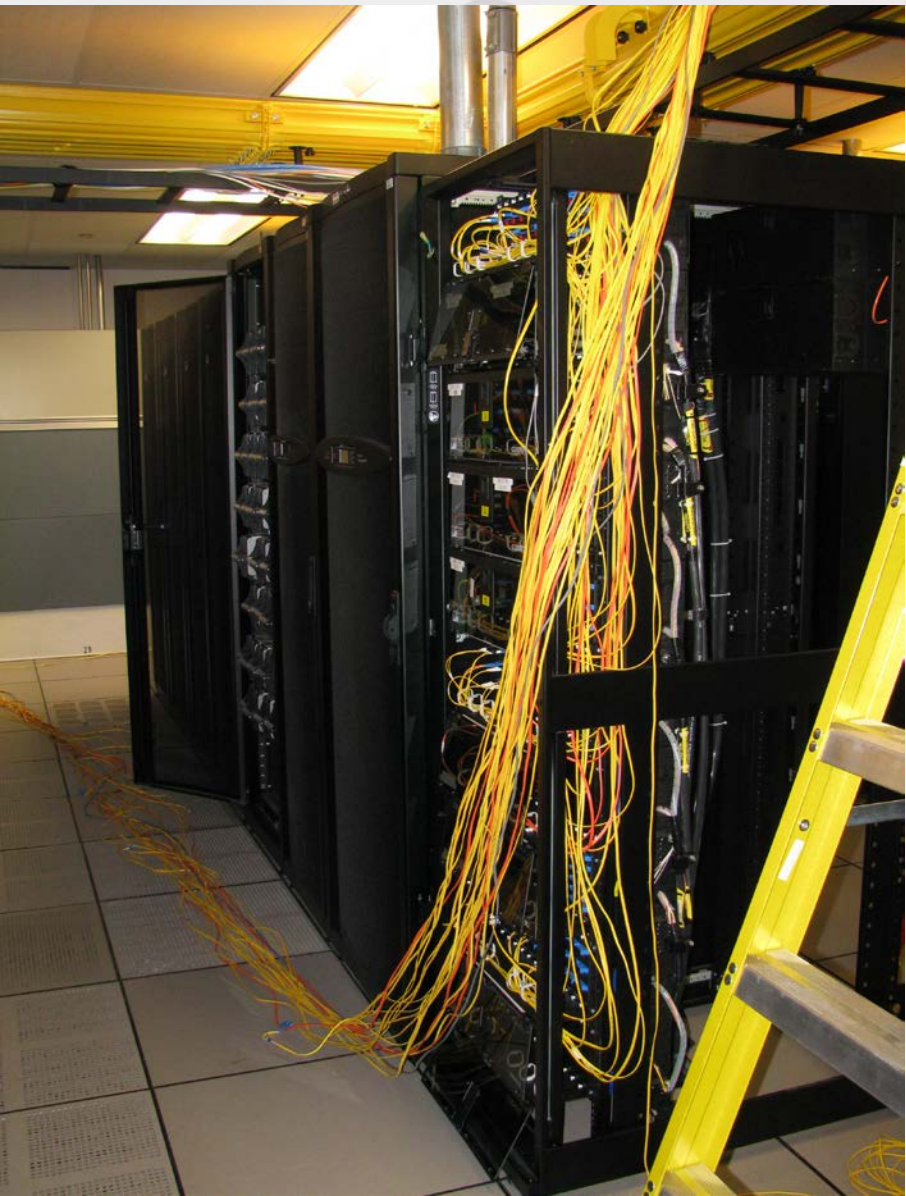
After



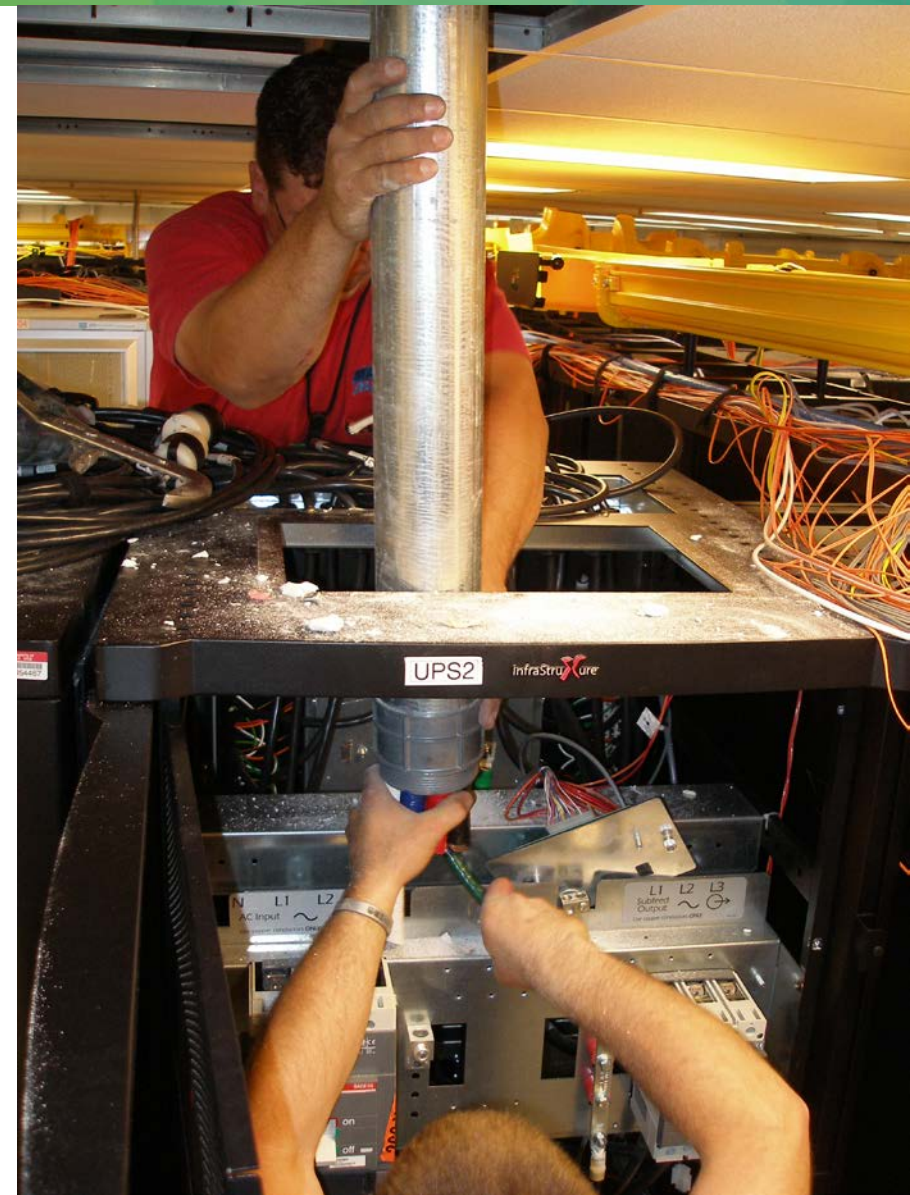
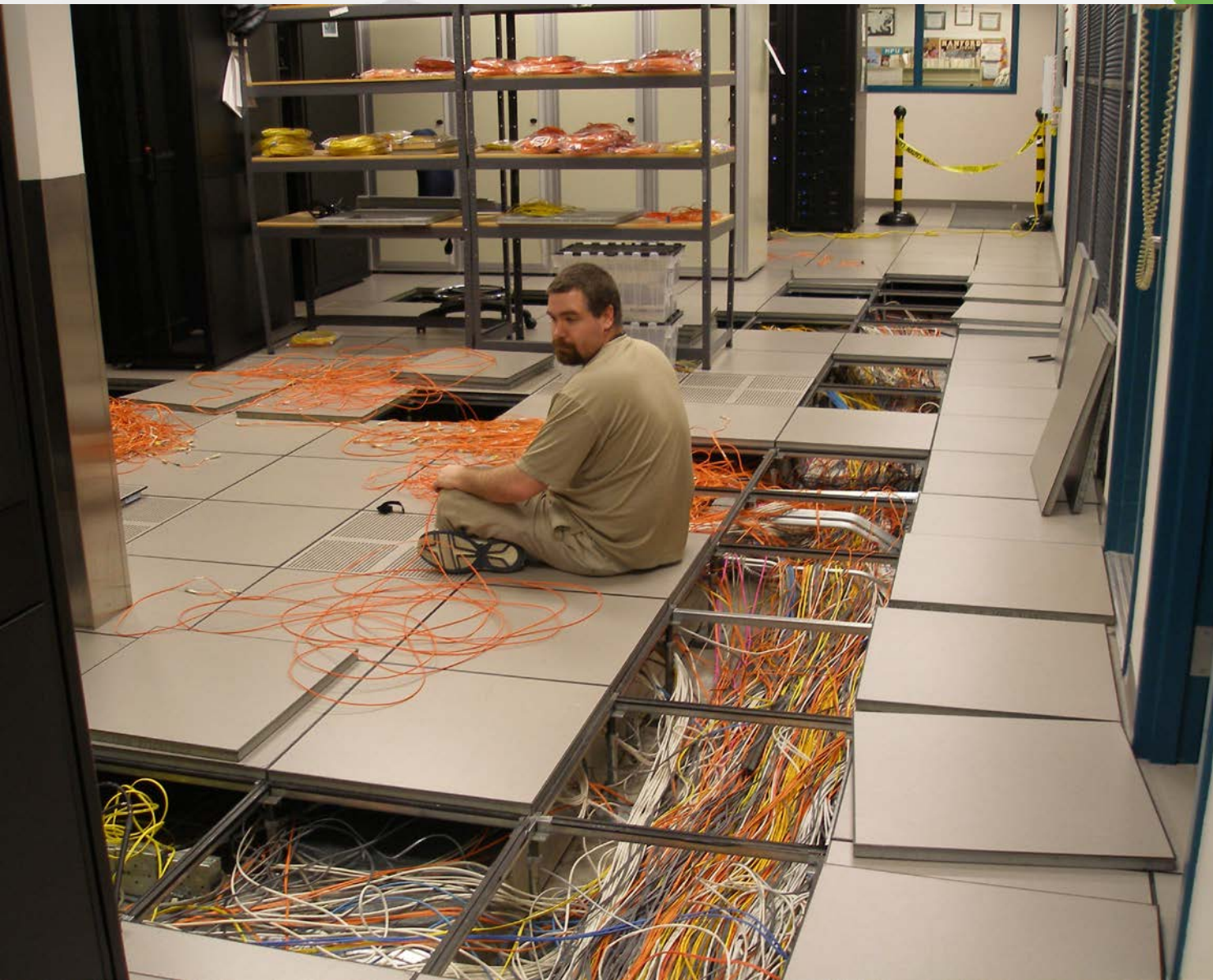


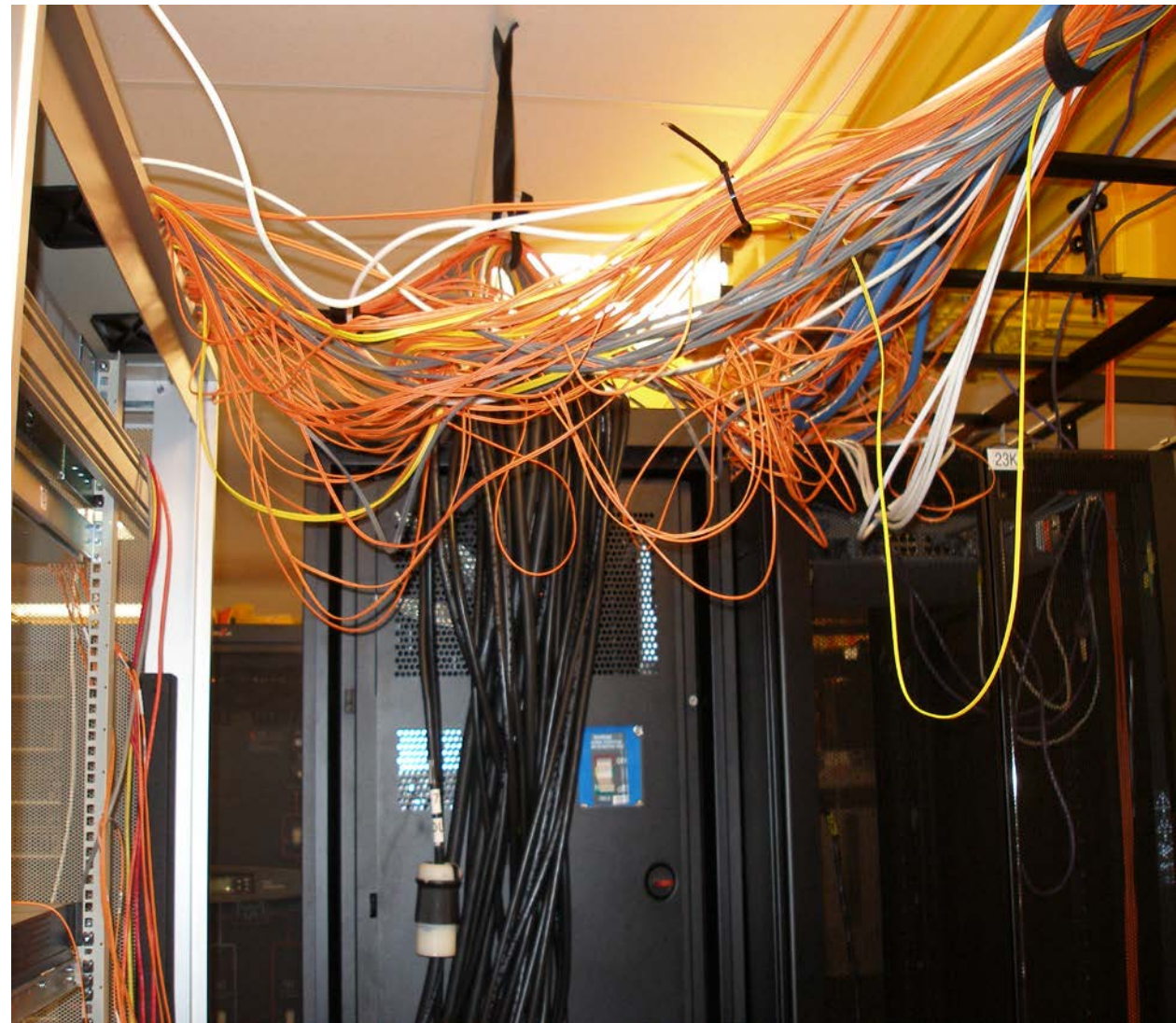


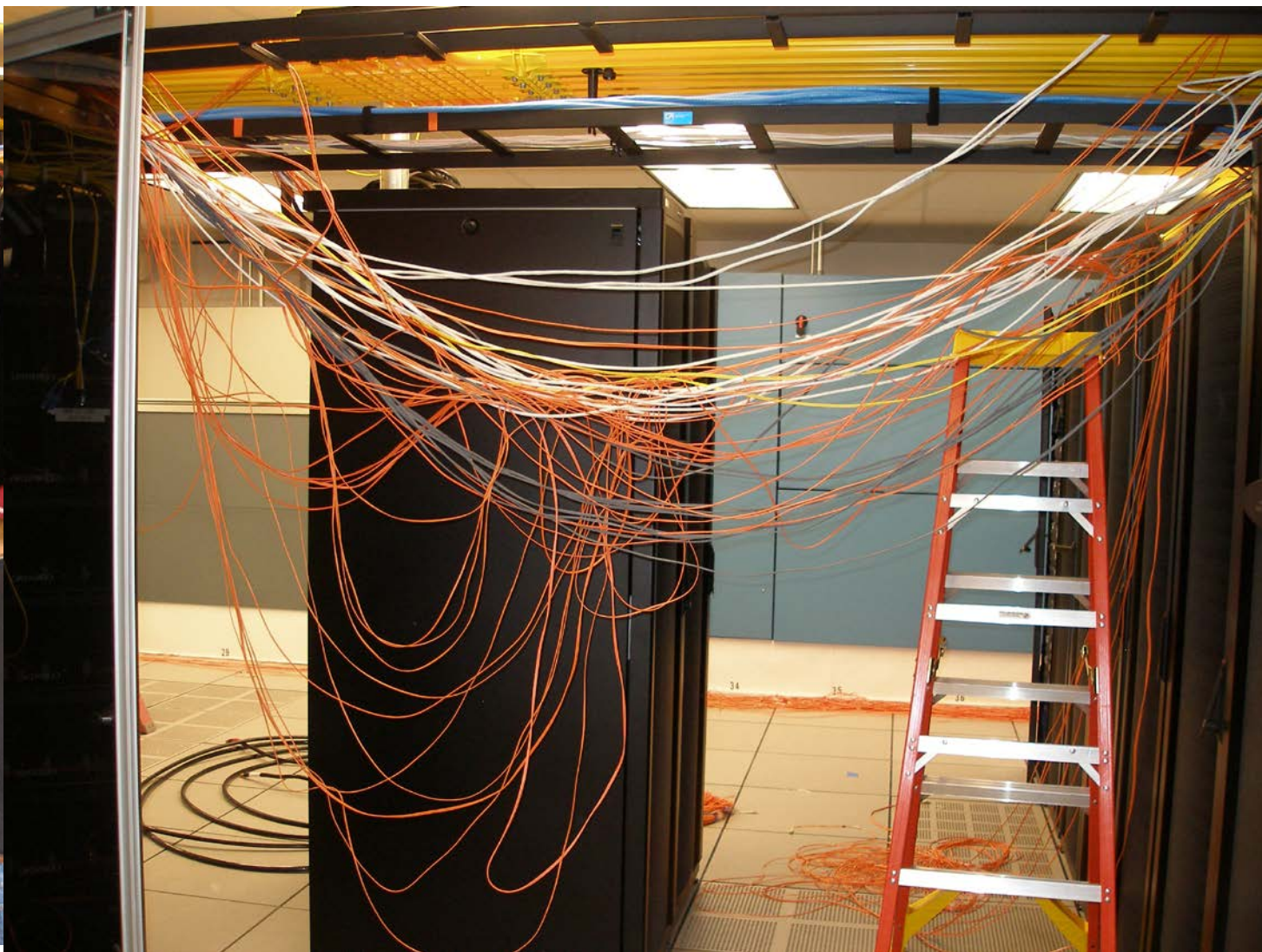


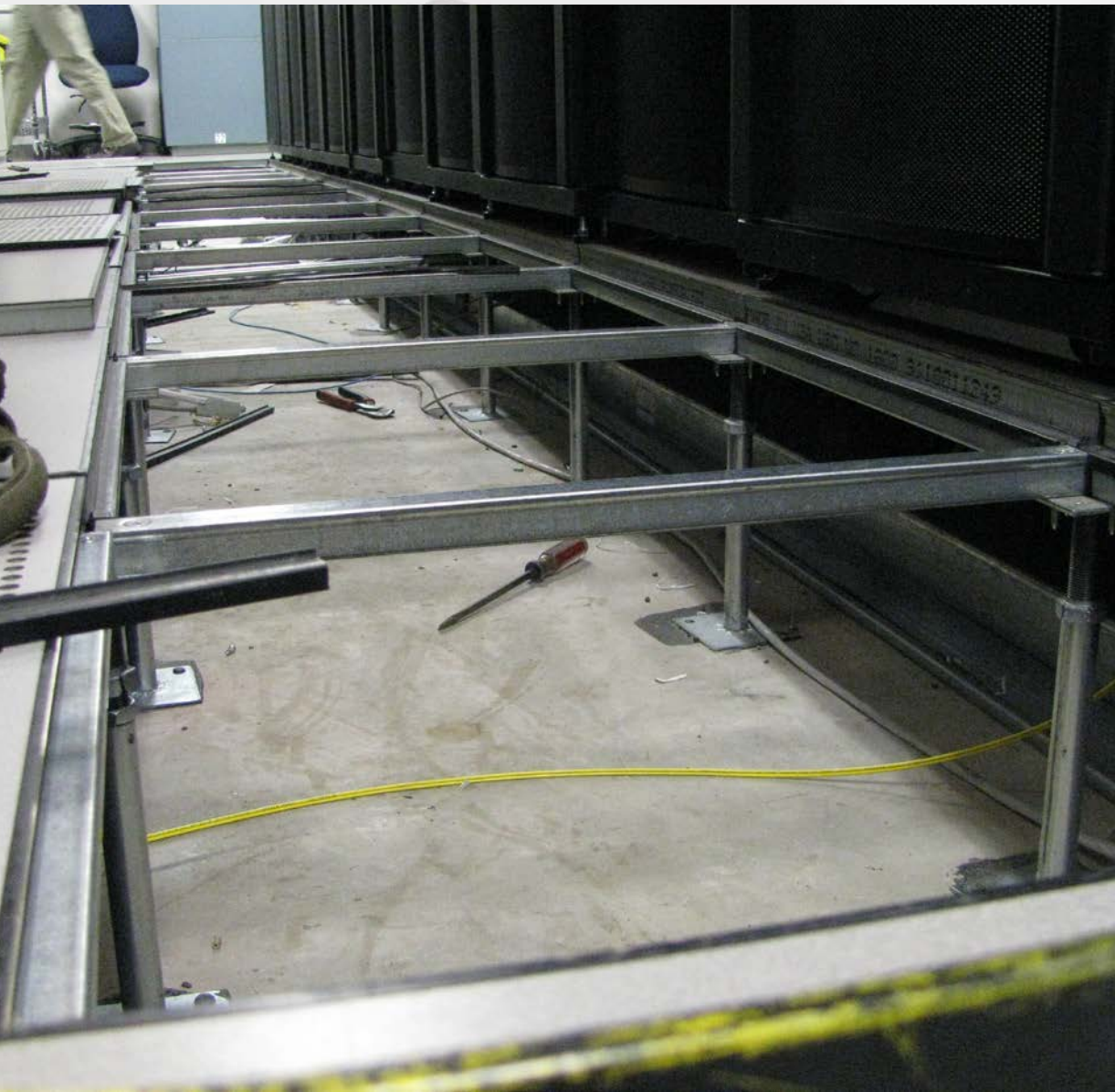












Before



After

Move Power and Networking Cables above the Cabinets.
Decrease clutter and increase Cooling Air Flow.







Data Centers Consolidation



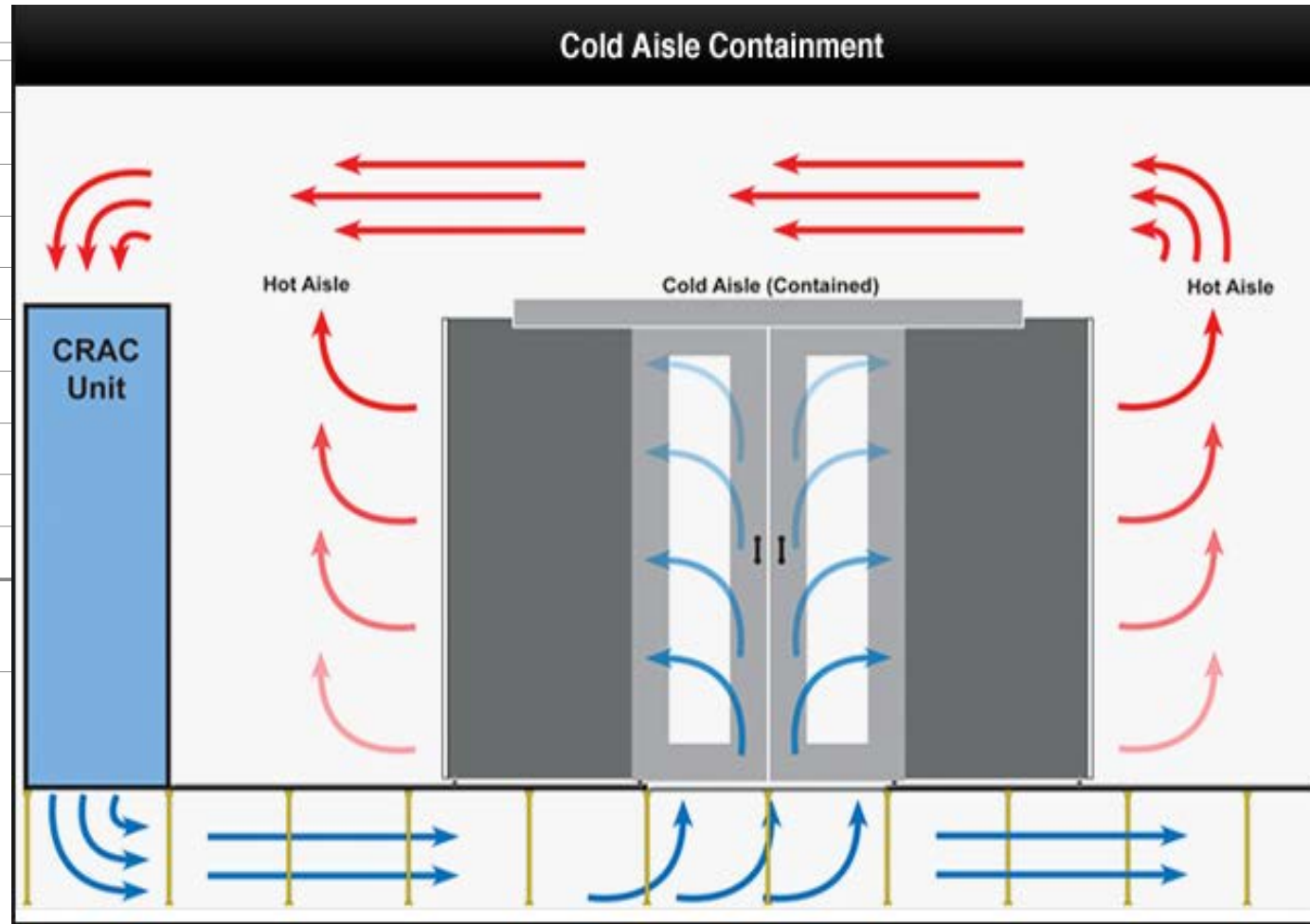
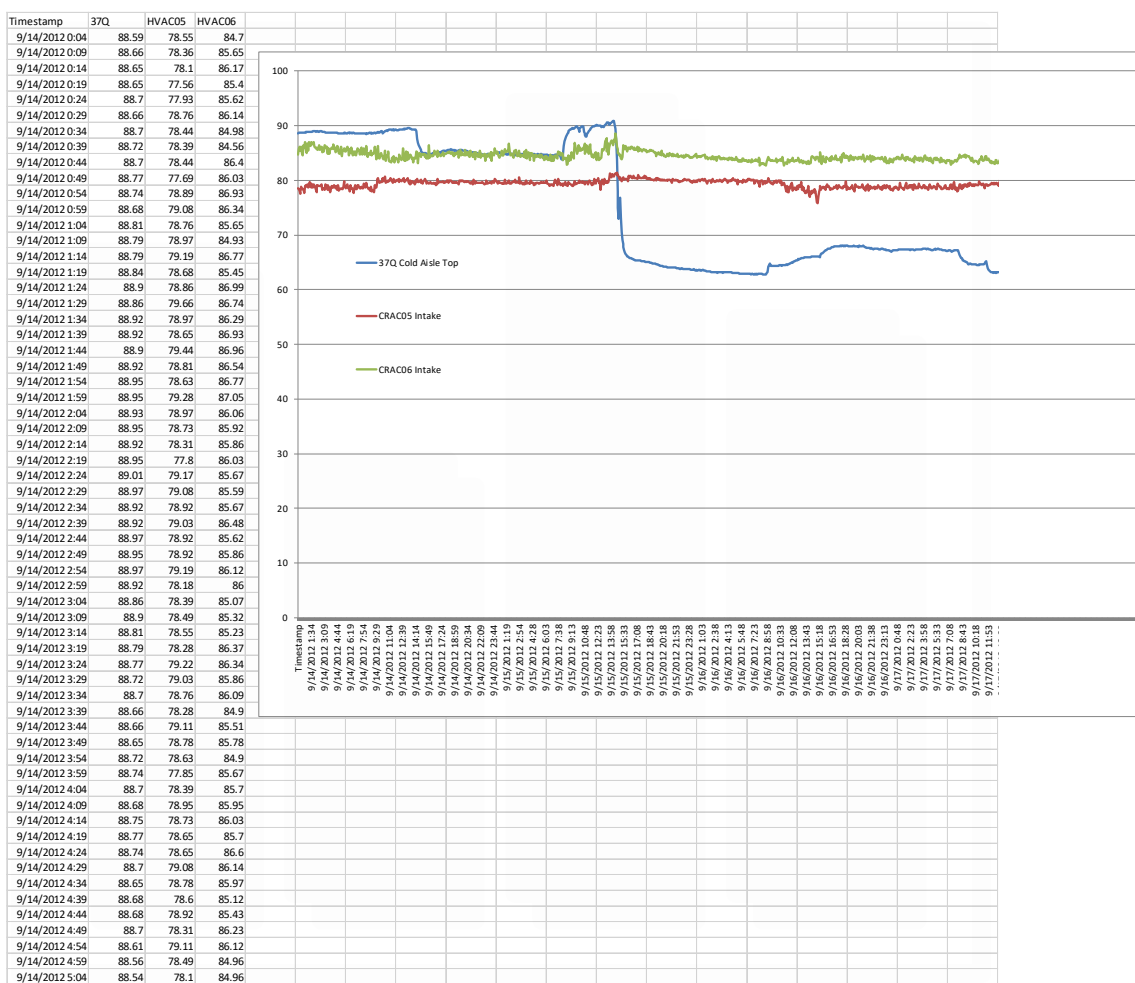
2011 New UPS4 Efficiency Results

- Replaced 2 old UPS's with single new technology 240V UPS
- Before installation – total power consumption 199.56kW
- After installation – total power consumption 182.68kW
- -16.88 kW reduction or 8.4% room-wide reduction
- New UPS4 only 37.5% of total room
- Therefore impact was -20% reduction in energy consumption for just the devices served by the new UPS

Cold-Aisle Containment September 2012

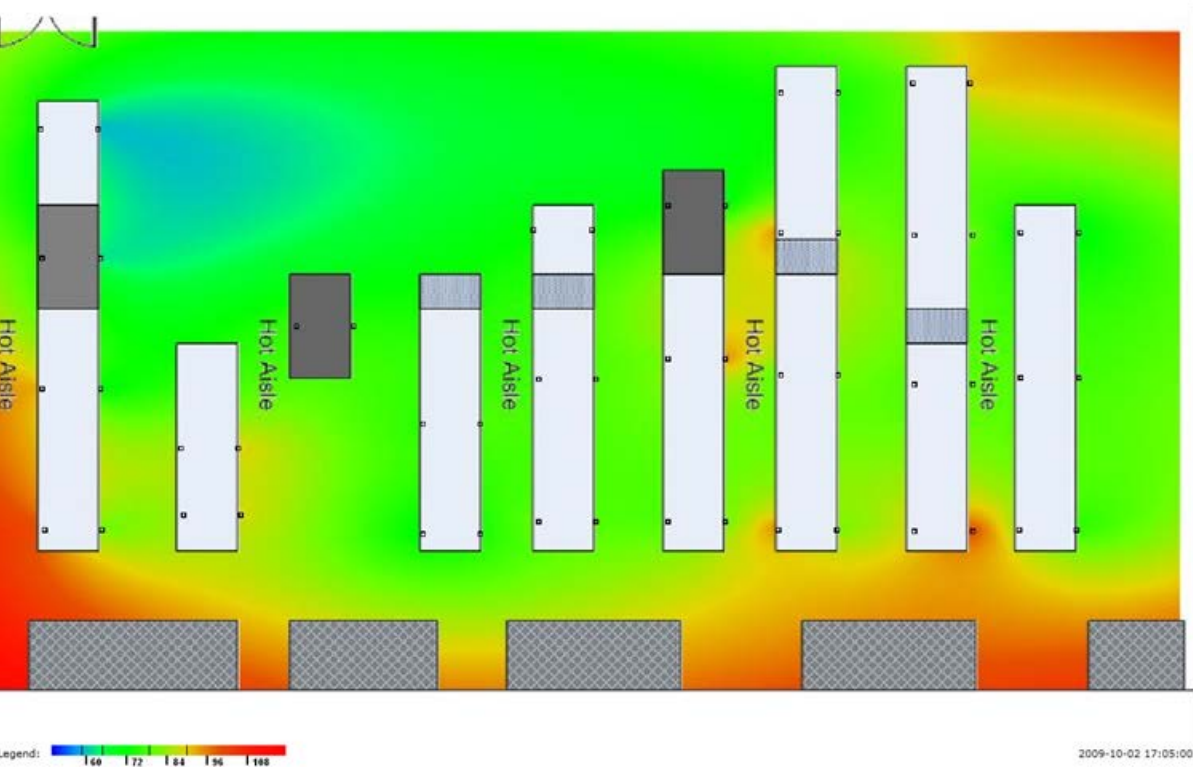


Cold-Aisle Containment Impact

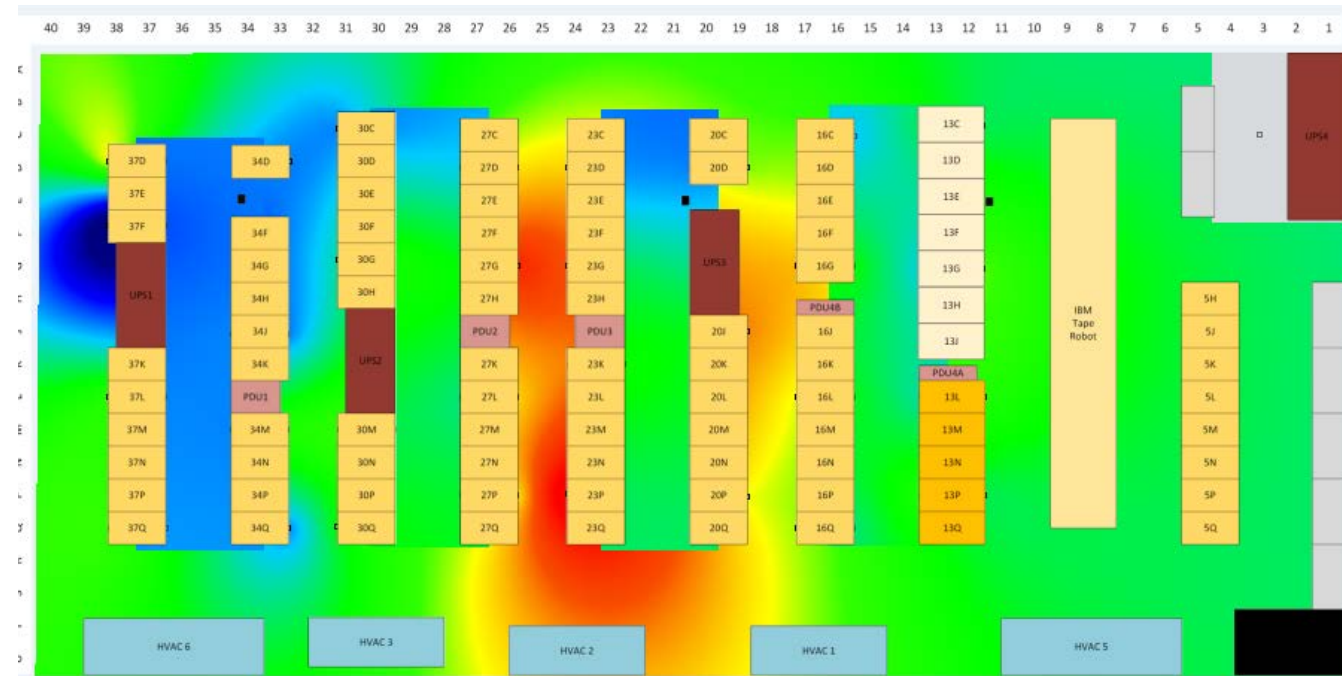


Cold-Aisle Containment Temperature Plume

2009



2018



PNNL Data Center Consolidation 2011

BUILDING	ROOM	SERVER COUNT	SQUARE FOOTAGE	CLASSIFIED	DATA CENTER / SERVER ROOM
APEL	163	10	1911	No	SERVER ROOM
CSF	1811	24	1435.5	No	SERVER ROOM
CSF	2527	194	1440	No	SERVER ROOM
CSF	2709	58	1059	YES	SERVER ROOM
CSF	2727	26	520	No	SERVER ROOM
CSF	2729	11	502	No	SERVER ROOM
CSF	2739	7	540	No	SERVER ROOM
CSF	2719a	6	64	YES	SERVER ROOM
EMSL	1121	15	200	No	SERVER ROOM
EMSL	1270	20	148	No	SERVER ROOM
EMSL	1553	138	478	No	SERVER ROOM
EMSL	1119/1125/1129	3098	9487	No	DATA CENTER
EMSL	1129/2nd onsite	8	272	No	DATA CENTER
ETB	103	65	976	No	SERVER ROOM
ETB	105	10	1158	YES	SERVER ROOM
ETB	104A	11	654	No	SERVER ROOM
ISB1	149	26	607	No	SERVER ROOM
ISB1	308	11	438	No	SERVER ROOM
ISB2	1	254	3,000	No	DATA CENTER
ISB2	403	11	135	No	SERVER ROOM
ISB2	4A	96	374	No	SERVER ROOM
LSB	1C04	254	757	No	SERVER ROOM
MATH	1316	12	504	No	SERVER ROOM
MATH	1419	40	379	No	SERVER ROOM
PSL	313	52	200	No	SERVER ROOM
Salk	125	77	3,000	No	SERVER ROOM

PNL Top Data Centers and Server Areas																				Analysis Results															
Space and Property Information													Sensitivity			\$ 50		Cooling		Analysis Input			Power Efficiency		Space Efficiency			Res Efficiency							
Bldg	Room	Type of Space	Research CSM	Org	Property Count of Computers	Average Age (yrs)	Average Cost per Computer	Total Computer Cost Within Space	Space Area (sq ft)	Self-Cont Lab (Y)	Data Center (Y)	Class-ified (Y)	Sens Unclass (Y)	Unclass (Y)	Annual Space Cost Est	Dedicated Units) or 24/7 HVAC	Count of Candidate Racks	Candidate Notes	Comments	Power Efficiency (Y)	Power Savings Annualized (\$)	Space (Y)	Space Returned (sq ft)	Space Annualized Savings (\$)	Research (Y)	Research Savings (\$)									
CSF	2527		Kutzke, Mitch		157	2.0	\$ 3,376	\$ 530,045	1,440		Y	some equip	most equip		\$ 72,000	4ea 20 ton HVAC; 250kVA UPS	12.0	up to 15 sensitive unclass	could consolidate classified into here there are 28 racks that can be consolidated into 15 racks	L			H	1,440	\$ 72,000			CSF Cage Opportunity	1.0	this room may become classified CRAY space cages needed in 1811 frees up capacity for classified computing - HVAC is very inefficient 5 locked racks already planned to move to CSF;	5keep				
ETB	103	Computer Lab	Homer, Brian CBP storage and backup		15	4.1	\$ 3,615	\$ 54,223	976		Y		Y (Law Enforcement)	Y	\$ 48,800	Dedicated Mammoth unit shared with Rm 103 -- dual 5 ton	5.0	revert to offices	NSD space for CBP data and backup (100TB of data with multiple tape robots) "energy inefficient space" move robots to APEL	Y			Y	976	\$ 48,800			CFS Opportunity	1.0	Need determination on locked cabinets- relocate 4 racks (35 computers and 2 tape robots) of equipment to CSF; can reuse existing locks or hasps.	4space returned		976		
ETB	104B	Computer Lab	Ward, Duane Hydrology		28	7.2	\$ 6,297	\$ 176,324	654					Y	\$ 32,700	Dedicated HVAC and UPS	1.0	extremely old systems on shelves	Hydrology for Army Corps of Engineers	Y			Y	654	\$ 32,700				3.0	need deep dive to determine modernization approach (reduce to 4U?) color of money may be issue need investment to provide replacement systems					
ETB	1415	Common Space LAN Closet	ARM backup		1			\$ -	313		Y			Y	\$ 15,650		1.0	rack of servers	tape backup; ARM backup; storage; tape robot	Y			Y	25	\$ 1,250				3.0	reduce building HVAC usage and setback issues					
SB1	410	Network Closet Common Space	Homer, Brian	?	3			\$ -	62						\$ 3,100		0.5	rack of servers	on building HVAC	Y			Y	62	\$ 3,100				3.0	reduce building HVAC usage and setback issues					
SB1	412	Lab and Office	STIDP project	STIDP	3			\$ -	412	Y					\$ 20,600		0.3	rack of servers	project may be coming to a close	Y			Y	412	\$ 20,600				3.0	reduce building HVAC usage and setback issues					
LSB	1C04	Computer Lab	EMSL 25% FCSD 50% Other 25%		225	4.8	\$ 5,190	\$ 1,167,647	657		Y			Y	\$ 32,850	Dedicated 20 ton, 2ea 5 ton, 166 ton / cabinet UPS	8.0	2 Shaun, 6 FCSD	need to vacate; poor HVAC and energy efficiency	H	reduces building power consumption by 40%?	H	657	\$ 32,850			CSF Opportunity	1.0	Relocate 11 racks of equipment to CSF; all systems are older than 18 months	11space returned		657			
MATH	1316	Computer Lab	Wescott, Ralph E		17	3.8	\$ 3,716	\$ 63,164	1,044						\$ 52,200	2 Dedicated Liebert units	2.0	already planned	includes telephone system	Y			Y	1,044	\$ 52,200				3.0	move to more efficient space					
PSL	313	Server Room (313)	Larsen, Jeff	NSD	39			\$ -	139				Y		\$ 6,950	Dedicated Liebert	2.0	needs cage	flooding; HVAC failure (no redundancy)				Y	139	\$ 6,950	Y		CFS Cage Opportunity	1.0	Determine if locked cabinets are sufficient for PSL computers- 3 racks (57 computers) in CSF to support. Can go to ETB 103 if can't get locked cabs in CSF.	3space returned		139		
Sigma 3	411	Computer Lab	Walling, Rick Rohlfing, KS	NSD?	10	4.6	\$ 1,807	\$ 18,074	204					Y	\$ 10,200	Dedicated cooling unit in ceiling	0.3	old equipment	strong candidate to return space	Y			Y	204	\$ 10,200				3.0	modernize and relocate					
EMSL	1553	Computer Lab	Larsen, Jeff		166	5.9	\$ 8,174	\$ 1,356,950	478		Y			Y	\$ 23,900	Dedicated Liebert Unit	5.0	revert to offices					Y	478	\$ 23,900				2.0	one rack has complicated rack power issues					
SB1	149	Computer Lab	McDuff, Matt		52	3.8	\$ 8,736	\$ 454,247	607		Y		Y	Y	\$ 30,350	Dedicated Liebert Unit / UPS	5.0	relocate to CSF revert to offices?	contains fiber patch rack				Y	607	\$ 30,350			CSF and APEL opportunity (will need APEL investment for power mod)	1.0	Move SGI to APEL, FCSD cluster to CSF, and provide 3 Racks in CSF for ARM; will need total of 5 racks in CSF	5space returned		607		
SB1	308	Computer Lab	general project space	NSD	31	2.8	\$ 2,779	\$ 86,158	438	Y					\$ 21,900	requires 24/7 operation	0.5	revert to offices?	FEMIS Lab; storage? 5 cubes 1 rack				Y	438	\$ 21,900				3.0						
APEL	163	Computer Lab	Peterson, Michael R		44	4.8	\$ 49,825	\$ 2,192,293	1,911		Y		1 rack?	Y	\$ 95,550	Dedicated Liebert Unit	3.0	Unclassified racks	2 Cray XMTs, 1 Cray CX1	Y				1,911	\$ 95,550				3.0	very good place to house systems with "odd" power requirements; existing 10PB tape robot has 3 years left					
EMSL	1119	Computer Lab (main supercomputer lab)	Wright, Ryan		406	3.6	\$ 7,013	\$ 2,847,087	4,691		Y		Y	Y	\$ 234,550	Supercomputer Room (16 Liebert Units)	10.0	planned to relocate to CSF					Y	4,691	\$ 234,550			CSF Opportunity	1.0	Relocate 5 racks to clusters to CSF: milcluster 1, 2, and 3. Sysbio, paris, and gnodo2 clusters.	5keep				
EMSL	1553	Computer Lab						\$ -	478						\$ 23,900									478	\$ 23,900			CSF and APEL opportunity (will need APEL investment for power mod)	1.0	Relocate 5 Proteomics racks to EMSL 1119. Relocate 2 Verari racks to APEL (Power incompatible with CSF;	space returned		478		
ETB	2218	Office Graphics Lab		JCGRI	3		\$ -		129					Y	\$ 6,450		-	needs HVAC		Y					\$ -			3.0	set-back savings may include ancillary space heater effects						
ETB	2220	Graphics Lab		JCGRI	6		\$ -		129					Y	\$ 6,450		-	needs HVAC		Y					\$ -			3.0	set-back savings may include ancillary space heater effects						
Sigma 4	213	Single office Unfronted	Pucycki, David J	NSD	1	3.0	\$ 3,457	\$ 3,457	140				Y	Y	\$ 7,000	???		no answer until 7/6	strong candidate to return space	Y			Y	140	\$ 7,000				3.0	likely already empty but not released to become office space					
Sigma 5	2407	Computer Lab raised floor with offices	Clayton, Ray Rohay, Allen Dirkes, Gayle Simmons, Mary Ann	0.75 Ecology 0.125 Seismic 0.125 Hydrology	29	8.4	\$ 5,186	\$ 150,406	696					Y	\$ 34,800	Dedicated 20-ton Compaire CRAC	0.8	rack with cluster TAGVIZWEB remainder of systems are PCs	area is mostly offices; move server equipment to better managed, more efficient space	Y			Y	16	\$ 800				3.0	not a strong candidate					
Total							\$ 9,100,075		15,598	2	8	1	7	13	\$ 779,900			56.3			\$ -		14	16	14,372	\$ 718,600	\$ -		20		33		2857		

2012 Consolidation Tasks

PNNL Top Data Centers and Server Areas

Space and Property Information						Analysis Results			
						Analysis Input		Space Efficiency	
Bldg	Room	Type of Space	Research CSM	Org	Space Area (sqft)	Count of Candidate Racks	Space Returned (Y)	Space Returned (sq ft)	Opportunity Description
CSF	2527	Computer Lab	Kutzke, Mitch	NSD	1,440	5.0			CSF Opportunity
ETB	103	Computer Lab	Homer, Brian	NSD	976	4.0	Y	976	CFS Opportunity
LSB	1C04	Computer Lab	(various)	EMSL 25% FCSD 50% Other 25%	657	11.0	Y	657	CSF Opportunity
PSL	313	Server Room (was 309)	Larsen, Jeff	NSD	139	3.0	Y	139	CFS Opportunity
ISB1	149	Computer Lab	McDuff, Matt	NSD	607	5.0	Y	607	CSF and APEL opportunity (will need APEL investment for power mod)
EMSL	1119	Computer Lab (main supercomputer lab)	Wright, Ryan	EMSL	4,691	5.0			CSF Opportunity
EMSL	1553	Computer Lab		EMSL	478	(move equip to EMSL 1119 and APEL)	Y	478	CSF and APEL opportunity (will need APEL investment for power mod)
Total	7				8,988	33.0	5	2,857	

2012 Consolidation Tasks

- ISB2/1
- Cold aisle containment – 4 doors at \$1,500 each = \$6,000 + Crafts installation
- Cold aisle containment – 4 rows of overhead “soft” roofing and sprinkler/fire sensing alterations = \$10,000
- CRAC autostart – CRAC1,2,3 should have autostart installed to avoid wasting energy by keeping the N+1 always running – SIGMA - \$10,000
- CRAC louvers – CRAC1,2,3 should have louvers installed to prevent chilled air backflow waste - \$3,000
- CRAC4,5,6 EC fans – replace squirrel fans with EC plug fans – save 30% fan energy - \$40,000 (CSF already has these advanced fans)
- Install underfloor thermostats for CRACs, reprogram CRACs + \$5,000
- Final sensors for Synapsense – part of CSF install
- Meters for measuring lighting = \$3,000 SIGMA
- Motion sensing light switches = \$2,000 SIGMA
- CSF/1811
- Hot aisle containment – row 1 only for now - \$10,000 + installation
- VESDA fire alarm system - \$25,000
- Ceiling tile 100% grates – 30 tiles = \$3,500
- Move wall thermostats to underfloor and reprogram CRACs - \$5,000
- Synapsense initial installation = \$7,000 onsite with programming
- Meters for CRAC power measuring = \$3,000
- Programming the Alerton System by Apollo for PUE data gathering = \$6,000
- Programming to get Alerton data into Synapsense = \$5,000
- Programming Alerton System to incorporate output from RDHx PLC outputs = \$2,000
- EMSL/1119,1125
- Enable ceiling plenum air return = \$100,000 (real swag)
- Data Collection = no estimate for metering or programming at this time

LSB-1C04 Consolidation 2012



LSB-1C04 Consolidation 2012

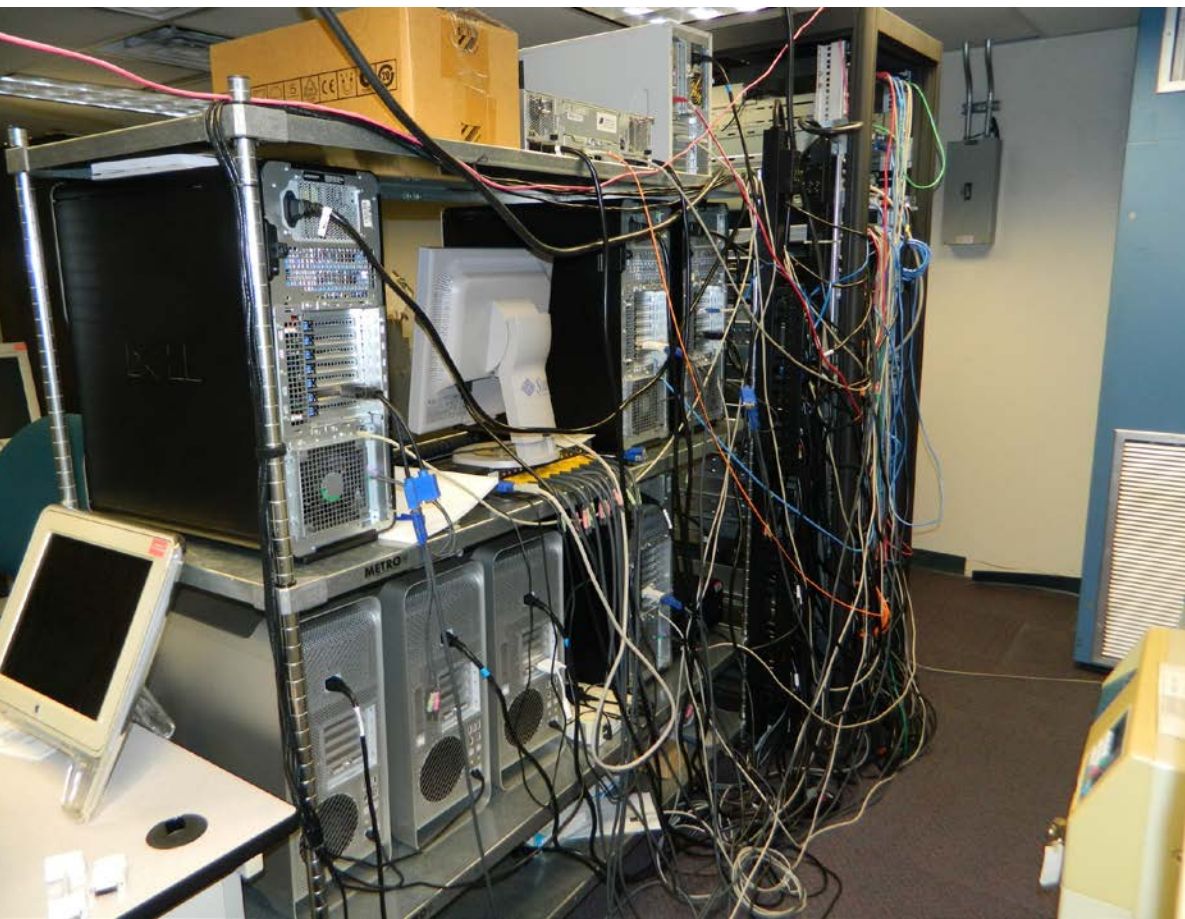


2013 Consolidation and Efficiency Tasks

Bldg	Room	Sq Ft	Power	Project Type	Contact	Cost	Notes	Status
ISB1	149	607	~10kW	Consolidation	Wescott	\$5k	excess Liebert UPS	Done
ETB	104B	654	~30kW	Consolidation	Ward, Duane	\$20k	PIC user, move to CSF, need deep dive, Hydrology, Andre Coleman	awaiting approval
ETB	1415	313	0kW	Consolidation	Wescott	\$0	excess tape robot, ARM backup servers and cabinet	Done
ISB1	410	62	tbd	Consolidation	Homer, Brian		need deep dive, network closet space	awaiting approval
ISB1	412	339	tbd	Consolidation	STIPD		need deep dive, project may be ending	awaiting approval
Sigma 3	411	204	tbd	Consolidation	Walling, Rohlfing		need deep dive, NSD?	awaiting approval
ISB1	308	438	tbd	Consolidation	NSD		need deep dive	awaiting approval
ETB	2218	129	tbd	Consolidation	Graphics?		need deep dive	awaiting approval
ETB	2220	129	tbd	Consolidation	Graphics?		need deep dive	awaiting approval
Sigma 4	213	140	tbd	Consolidation			need deep dive	awaiting approval
Sigma 5	2407	696	tbd	Consolidation	Wescott		need deep dive, losing lease, Paul Dotson project	awaiting approval
Bldg 3410	1210	238	~6kW	Consolidation			Server Plies, shutdown CRAC	awaiting approval
2400 Stevens	2222	298	~10kW	Consolidation			qty=22 Servers, move or PIC	awaiting approval
ISB2	4	814	15kW	Consolidation/Efficiency	Wescott	\$10k	move room 4 servers into room 1, raise host aisle temp, replace wa	in process H80498
MATH	1316	1044	~20kW	Consolidation/Efficiency	Wescott	\$5k	move backup disks to EMSL/1125, shutdown single CRAC	awaiting approval
ISB2	1	3040	147kW	Efficiency	Wescott	\$10k	motion sensing lights for data center, seals, sensors, louvers, move	in process H80499
APEL	163	1911	~30kW	Efficiency	Peterson	\$5k	excess Liebert UPS	Done
ISB2	1	3040	147kW	Efficiency	Wescott	\$25k	EC Fan retrofit for CRACs with controls, 3 yr ROI	awaiting approval
EMSL	1119	9284	1500kW	Efficiency	Wescott	\$150k	Ceiling Plenum & partial hot aisle containment	awaiting approval
EMSL	Mechanical	9284	1500kW	Efficiency	Wescott	\$55k	install meters and sensors	in process H80093
EMSL	1119	9284	1500kW	Efficiency	Wescott	\$25k	install Synapsense metering	Hold per Larry
EMSL	1119	9284	1500kW	Efficiency	Wescott	\$100k	qty=10 EC Fan upgrades	awaiting approval



ETB-103 Consolidation 2013



Energy
Exchange

Better Buildings[®]
SUMMIT

ETB-103 Consolidation 2013



Client Benefits from Consolidation

- Increased Security (Prox, Surveillance, Fire Protection)
- 7x24 Monitored Cooling and Power Distribution
- Higher Energy Efficiency
- Researchers can now focus on Research, not Server Admin
- Faster Managed Network Connection
- Faster Application Run-time Virtual or Standalone
- 3 Year Warranty with New Servers
- Funded Application Code Porting

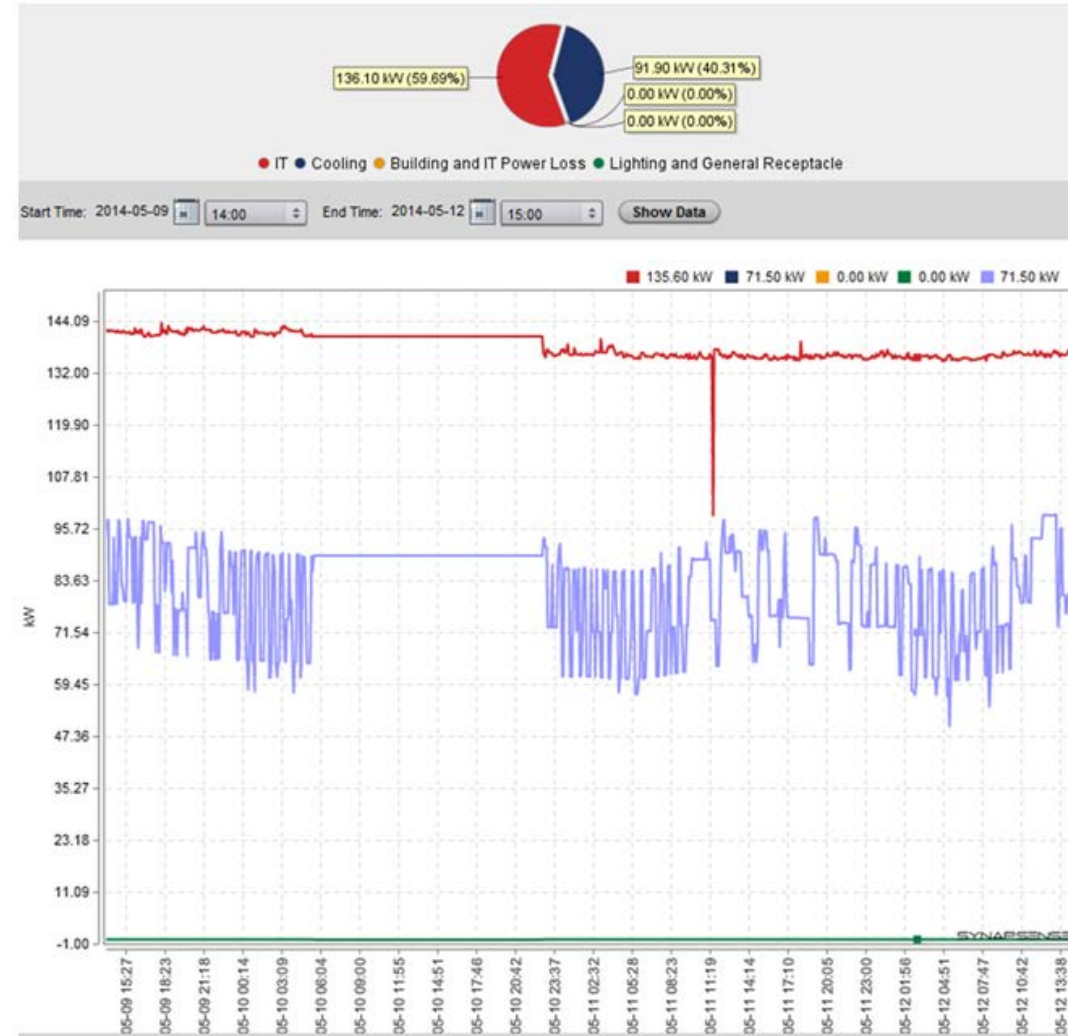
2013 Consolidation Savings

Description	Before	After	Decrease/Savings
IT Load	188kW	84.6kW	55% IT Load
PUE	2.5	1.2	1.3 87% more efficient
Cooling Load	288kW	16.9kW	94% cooling
Total Energy Use	476kW	101.5kW	79% energy
Cost at \$.05/kwhr	\$208,488 annually	\$44,465 annually	\$164,023 savings
Computer Cabinets	67	27	60% Decrease
Square Feet Occupied	2,857	432	85% Decrease

Incremental Energy Savings

Incremental Savings February 2014

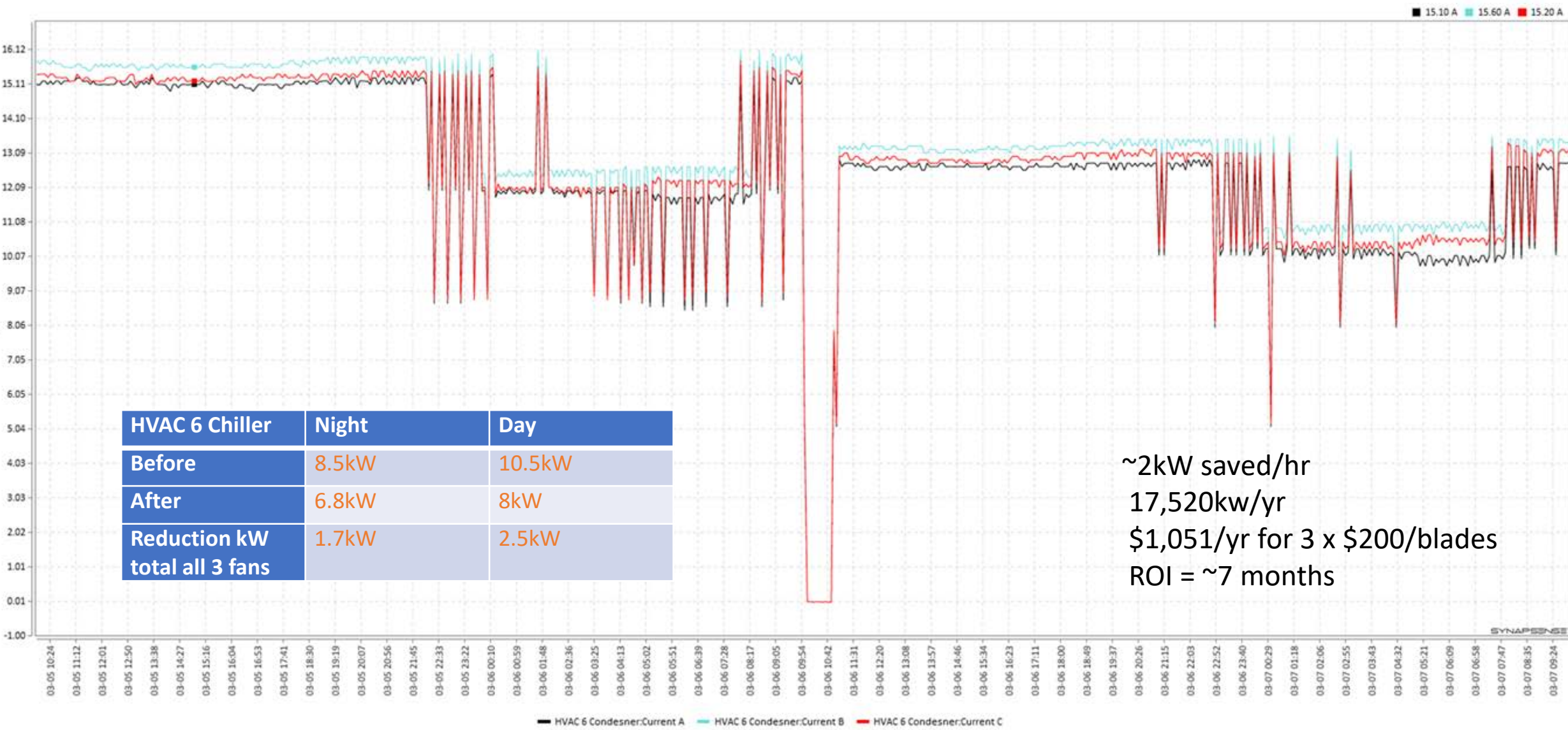
- 172kW IT Load
- 141.7kW IT Load after zombie server reduction
- 30.3kW reduction or 17.6%
- 135.6kW IT Load after FEX switch swap-in for old CISCO 6500's
- 6kW Reduction or 4.2% further reduction
- \$19,079 annual savings IT Load and another ~\$10,000 in Cooling Savings.



Simple Energy Savings Ideas are Everywhere

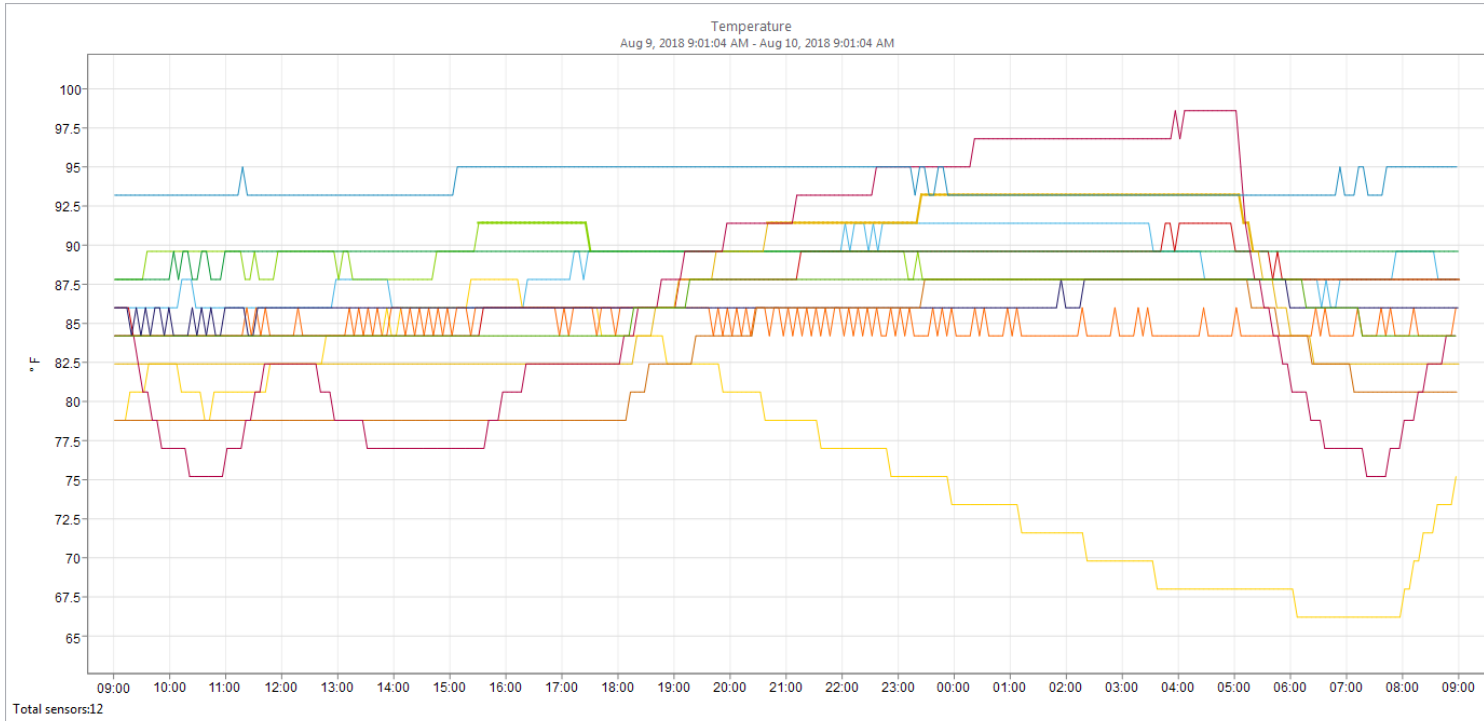














Install Airfoil Fan Blades to Chiller March 2018



Unintended Consequences

LAN Closets and Building Setbacks



Color	Monitored Device	Sensor	Units	Last Know...	Minimum ...	Maximum ...	Average Va...	Delta Value	Location	Parent Device
	isb2-406-dcem01 (10.80.42.14)	Temperature - Port 1:Sensor 1 (Port 1...	° F	84.2	75.2	98.6	86.4	23.4	ISB2-406	kraken (StruxureWare Data Center Ex...
	bsel-100T.net.pnl.gov (10.80.64.21)	Temperature - Port 1:Sensor 1 (Port 1...	° F	95.0	93.2	95.0	94.0	1.8	BSEL-100T	kraken (StruxureWare Data Center Ex...
	isb1-506-dcem01 (10.80.42.12)	Temperature - Port 1:Sensor 1 (Port 1...	° F	82.4	82.4	93.2	86.8	10.8	ISB1-506	kraken (StruxureWare Data Center Ex...
	apel-51-dcem01 (10.80.18.9)	Temperature - Port 1:Sensor 1 (Port 1...	° F	87.8	84.2	91.4	87.3	7.2	APEL-51	kraken (StruxureWare Data Center Ex...
	psl-1510-dcem01 (10.80.34.22)	Temperature - Port 2:Sensor 1 (Port 2...	° F	87.8	87.8	91.4	88.8	3.6	psl-1510	kraken (StruxureWare Data Center Ex...
	325-20 (10.80.22.10)	Temperature - Port 1:Sensor 1 (Port 1...	° F	87.8	86.0	91.4	88.6	5.4	325-20	kraken (StruxureWare Data Center Ex...
	bsel-200T (10.80.64.22)	Temperature - Port 1:Sensor 1 (Port 1...	° F	89.6	87.8	89.6	89.5	1.8	BSEL 200T	kraken (StruxureWare Data Center Ex...
	msl5-108-dcem01 (130.20.40.15)	Temperature - Port 1:Sensor 1 (Port 1...	° F	84.2	84.2	87.8	86.0	3.6	MSL5-108 Sequim	kraken (StruxureWare Data Center Ex...
	ROB-1100 (10.80.34.28)	Temperature - Port 1:Sensor 1 (Port 1...	° F	80.6	78.8	87.8	82.8	9.0	ROB-1100	kraken (StruxureWare Data Center Ex...
	bpo-14-dcem01 (130.20.42.10)	Temperature - Port 1:Sensor 1 (Port 1...	° F	86.0	84.2	87.8	86.2	3.6	BPO/14 Portland	kraken (StruxureWare Data Center Ex...
	PDLE-1-dcemon01 (10.80.36.25)	Temperature - Port 1:Sensor 1 (Port 1...	° F	75.2	66.2	87.8	77.3	21.6	PDLE-1	kraken (StruxureWare Data Center Ex...
	apel-170 (10.80.18.5)	Temperature - Port 1:Sensor 1 (Port 1...	° F	86.0	84.2	86.0	84.9	1.8	APEL-170	kraken (StruxureWare Data Center Ex...



Questions?

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